

UNCLASSIFIED

AD _____

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION ALEXANDRIA, VIRGINIA

DOWNGRADED AT 3 YEAR INTERVALS:
DECLASSIFIED AFTER 12 YEARS
DCD DIR 5200.10



UNCLASSIFIED

THIS REPORT HAS BEEN DECLASSIFIED
AND CLEARED FOR PUBLIC RELEASE.

DISTRIBUTION A
APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

AD No. 10629

ASTIA FILE COPY

TECHNICAL REPORT NO. 6130

ALL-PURPOSE FIRE-EXTINGUISHING FOAMS

J. M. PERRI
B. SLOVITER

NATIONAL FOAM SYSTEM, INC.

NOVEMBER 1952

WRIGHT AIR DEVELOPMENT CENTER

ALL-PURPOSE FIRE-EXTINGUISHING FOAMS

J. M. Perri

B. Sloviter

National Foam System, Inc.

PART OF THIS DOCUMENT NOT REPRODUCIBLE

Library
610 333-22946
664-739

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

AF TECHNICAL REPORT NO. 6130

ALL-PURPOSE FIRE-EXTINGUISHING FOAMS

J. M. Perri

B. Slotter

National Foam System, Inc.

November 1952

Equipment Laboratory

Contract No. AF 33(033)-22946

E.O. No. 664-739

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report covers an investigation into the development of All-Purpose Fire-Extinguishing Foam by the National Foam System, Inc. for the United States Air Force under Contract No. AF33(033)-22946, P.R. No. 102357, and Expenditure Order No. 664-739, Fire Prevention. It was initiated by Mr. R. R. Stasiak and administered by Captain E. C. King under the direction of the Equipment Laboratory, Directorate of Laboratories, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Acknowledgement is made for the work on surface tension and film measurements conducted under the direction of Dr. F. J. Hazel, University of Pennsylvania, Philadelphia, Pa.

ABSTRACT

An investigation into the development of an all-purpose fire-fighting foam is reported. The foam liquid has all of the desirable characteristics of the mechanical foam liquid described as Type 5 in the U. S. Government JAN C266 specifications with the added property of forming a foam which is effective in the extinguishment of fires involving ethyl alcohol. Soaps, alkyl aryl sulfonates, alcohol sulfates, proteins, glucosides, pectin and algin derivatives and quaternary ammonium compounds were all evaluated individually and found wanting. The components of ordinarily insoluble soaps were homogeneously incorporated into an aqueous base of hydrolyzed protein by means of a solubilizer, sodium diisopropyl naphthalene sulfonate. Procedures for manufacturing and testing the foam liquid are given. Surface tension measurements were made on foam liquids which served as precursors to this development.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:



RICHARD STOLLE
Colonel, USAF
Acting Chief, Equipment Laboratory
Directorate of Laboratories

CONTENTS

	<u>Page</u>
INTRODUCTION - - - - -	1
LITERATURE SURVEY and BIBLIOGRAPHY- - -	3
EXPERIMENTAL - - - - -	20
Foam Liquid Characteristics- - -	28
MANUFACTURING PROCEDURES - - - - -	34
SURFACE TENSION STUDIES - - - - -	36
SURFACE FILM STUDIES - - - - -	47

INTRODUCTION

The purpose of this investigation was to develop a fire-fighting foam liquid conforming generally to the U. S. Government Specifications JAN C-266 and possessing further the characteristics of low temperature performance and effectiveness on ethyl alcohol fires.

The practical compositions for foams used in combating alcohol fires contain soluble fatty acid soaps as primary foaming agents and heavy metal salts of fatty acids as the stabilizers. Such a system is further characterized by the presence of a "solubilizing agent". The stabilizer, or component which renders the foam alcohol-resistant, is necessarily insoluble in aqueous medium; it is the deposition of this solid material in the wall of the foam bubble that confers stability in the presence of alcohol. The "solubilizing agent" is necessary to the maintenance of homogeneity of the foam liquid in its "concentrate" form. On dilution, as in use, the solubilizer is no longer present in effective concentrations and the insoluble stabilizer precipitates. The system comprised of fatty acid soaps lacks compatibility with sea water. One of the more important investigational aspects therefore was to develop a colloidal system or systems from materials whose effectiveness is not diminished in the presence of sea water. The compositions of closely related materials considered came from the following classes of chemicals.

1. alkyl aryl sulfonates
2. quaternary ammonium compounds

Individual approaches to each class, attempting to establish suitable foaming agents which would also be capable of solubilizing the foam stabilizer, yielded limited results.

The combination lauryl pyridinium chloride and aluminum carboxy methyl pyridium stearate gave the best results. It was possible to formulate a homogeneous solution of the aluminum carboxy methyl pyridium stearate as stabilizer, using lauryl pyridinium chloride as a primary foaming agent and solubilizer. Pilot scale fire tests indicated, however, that rates of application greatly in excess

of that ordinarily recommended would be necessary to accomplish extinguishment. The lack of effectiveness was attributed to inability of the foam to withstand heat because of its being constituted primarily of low melting and low ash materials.

The ultimate composition obtained consisted of three primary ingredients which conferred on the composition the following characteristics:

- (1) Compatibility with sea water.
- (2) Stability toward alcohol.
- (3) Foam stabilized satisfactorily.
- (4) Foam with appreciable ash content.
- (5) Foam with high melting point.

A protein hydrolysate is the primary foaming agent and Nekal A (sod. diisopropyl naphthalene sulfonate) the solubilizing agent for the stabilizer. The stabilizer is a heavy metal salt of a fatty acid.

LITERATURE SURVEY

This search was made using Chemical Abstracts as a primary source of reference. The years 1907 to 1951 were covered.

In considering synthetic chemicals and those chemicals derived from natural products suitable for the production of stable foams for use in fire-fighting, it is the purpose of this report to summarize and catalog the various foam producing agents used in many different industries as well as those specifically employed at present by companies producing fire-fighting chemicals. Such uses as in the separation of ores in the flotation process; in the beverage and confection industry; in detergents and wetting agents in the soap industry; in the textile industry as a "textile assistant"; being some examples where the production of foams are desirable. It seems plausible that these foaming agents used in allied fields, having different and specific properties, may lend themselves as possible aids in producing fire-foam with varying characteristics.

Foaming agents can be divided into four general types:

1. Protein degradation products
2. Synthetic wetting agents
3. Soap solutions
4. Natural product extracts

The earliest use of natural product extracts and hydrolyzed proteins appears to have been in the use of foam stabilizers in chemical foam production. These include soap bark (1), quebracho and quillaya bark extract (2), licorice root extract (3,14,27), wood flour (4), chestnut oak bark extract (5), sulfite waste liquor (4,6,19), sugar or glue (7) with saponin solution as foaming agent, albumin (8),

alfalfa extract (9), a metal acetate known as purolignite (10), roasted peanut hull extract (11), alkali resin soaps (12) for stability against alcohol fires a compound known as "persil", FeSO_4 (13), phosphated sodium lauryl sulfate (15), diethylene glycol and glycerol (16), amino soaps (17), alkoxy acetic acid (18), soybean product (20), fat acid soap (21), sodium oetyl sulfate (22), ferrous chloride (23), extract of beets, turnips or swedes (24), salts of Fe, Cr, Ni, Al, Ca, Ba, (25), and urea with salts of Fe, Al, Cr, Ni, etc. (26).

Dilute aqueous solutions of saponin appear to have been the earliest method of producing mechanical foam satisfactorily with the use of suitable stabilizers. Subsequently, the presently used protein (13,35,23,25) degradation products came into wide use. Hydrolyzed albumin (31,32,33) was the first protein hydrolyzed, with many other natural products following soon thereafter. These include keratins (33,34), glue or gelatin (36), globulins and hemoglobulins (33), soybean flakes (37), α -soybean (20), casein (38), blood (39).

Foams suitable for extinguishing solvent fires, such as alcohol, acetone, etc., are produced under the following patents.

By adding to the usual foam producers, an alkaline soap, particularly an alkaline resin soap, e.g. "persil" (12).

A foam produced by a solution of a high molecular weight quaternary ammonium, phosphonium, or sulfonium compound (40).

By a stock solution of a water soluble fatty acid salt containing 7-11 carbon atoms, water soluble ammonium metal complex salt and protective colloids such as gelatin, albumin degradation products, cellulose, tragacanth, pectin, lignins, humic acids, etc., and salts of fatty acids with 4-12 carbon atoms (41,42).

By substituting some or all of the inert filler in the usual chemical foam generator powder, a portion of zinc stearate (43).

In contrast to the foaming agents derived from natural products are the synthetic organic compounds, whose use up to the present has been rather limited. These comprise the following group.

1. Alkyl aromatic sulfonic acids (31,44,45,46,47), e.g. sodium butyl naphthene sulfonate.
2. Water soluble salts of high molecular weight aliphatic amines, quaternary ammonium salts, phosphonium and sulfonium compounds (48,49,50, 51,49,59), e.g. dodecyldimethylamine, benzyl-dimethyl dodecyl ammonium chloride, lauryl pyridinium sulfate.
3. Water soluble salts of aliphatic amines of the ethylenediamine type (48), e.g. N,N-dodecyl-methylethylenediamine, diethyl heptadecylethylenediamine.
4. Aliphatic sulfonic acid derivatives of long chain fatty acid amides or amines (53,54,55), e.g. N-methyltauride of oleic acid.
5. Sulfonated hydrocarbons (45,56,57,58), e.g. sulfonated mineral oil, sulfonated benzene and petroleum distillate.
6. Miscellaneous molecules
 - (a) Aliphatic esters of anthranilic acid Hcl (51,59).
 - (b) Aliphatic sulfate esters of fatty acids (60), e.g. ethyl esters sulfate of oleic acid.
 - (c) Sugar esters of fatty acids (61), e.g. mannitan oleate, sorbitan laurate.
 - (d) Benzimidazole sulfonic acid with alkyl group in the 2 position (19), e.g. decylbenzimidazole sulfonic acid.
 - (e) Sulfonic derivatives of aldehyde-phenol condensation products (45).
 - (f) Triarylmethane dyes (62).
 - (g) Alkyl silicone trihalides (63), e.g. octadecysilicon trichloride.
 - (h) Water soluble salt of polycarboxylic acid (64,65), e.g. citric acid, tri-carballylic acid.

The soap and chemical industries, producers of detergents and wetting agents, have made many chemicals that have the property of foaming. These will be discussed as to the type of molecular structure rather than chronologically.

The first of the group of wetting agents with the ability to produce foam is the aromatic molecules with or without side chains and sulfonated in the ring. In 1947 in a patent by Johnson and Adams (66), benzene was alkylated and then sulfonated in the ring in excellent yield. Similarly, in 1929, I. G. Farben (67) patented an alkylated benzene sulfonate which was also halogenated in the ring. Gilbert and Otto in 1950 (68) patented an alkylated benzene molecule which was sulfonated in both the ring and the side chain. This produced a large decrease in surface tension at very dilute concentrations. Many compounds with capillary activity are produced by reacting an alkyl chloride with various amines; e.g. cetyl chloride with aniline disulfonate (69,71), benzaldehyde disulfonic acid with dodecyl amine (70), naphthalene amine sulfonic acid with dodecyl chloride (72,73). Flett (74) in 1936 sulfonated alkyl phenols, and similarly, I. G. Farben (75) reacted the phenol hydroxyl group with aliphatic aldehydes. In patents by Henkel & Cie (76,77), fatty acid esters with ether linkage are sulfonated, e.g. sulfonated dodecylphenoxyacetate. Similarly, fatty acid chlorides are made to react with aminoalkyl ethers as in patents held by Imperial Chemical Industries (78) and also by I. G. Farben (79). In patents to I. G. Farben (80,81), phenol is condensed with chloroacetone, chloroacetaldehyde, etc., and subsequently sulfonated. In 1929 H. Th. Bohme (82,83) patented aromatic esters of phenols, esterified with alkyl hydrocarbons or ether alcohols. In 1936, 1937, and in 1949, Swiss patents (84,85,86) were issued for benzimidazole derivatives said to have high acid resistance and strong foaming power. A Swiss (87) patent in 1942 reports strong foaming by condensing coconut fatty acid anilide with N-methylol chloroacetamide sulfonate. In making a soap-like compound Polasek (88) bleaches sulfonated naphthalene and mixes polymerized urea with it. J. R. Caldwell (89) in 1949 prepared the dialkyl ester of bis (2-hydroxyethyl) ether of hydroquinone, and then sulfonated.

In the aliphatic series, those compounds showing capillary activity appear to be ester or hydroxy ester aliphatic sulfonates. In patents by Daimler et al. to I. G. Farben (90, 91,92) in 1930 and 1933 and also a patent to Ciba Ltd. (93), an aliphatic hydroxy sulfonate, such as 1, 2, dihydroxy butane sulfonate and a fatty acid chloride such as stearyl chloride are condensed. In Swiss patents in 1933 (94) esters of sulfacetic acid were obtained by reacting such a compound as cetyl

ester of phloxacetic acid with neutral or acid sulfites. B. Harris (95) prepared relatively high molecular weight fatty acid esters with one of the alkyl radicals sulfonated. Ross (96) in 1947 prepared aliphatic sulfonates from olefins by making the sulfonyl chloride and then hydrolyzing which he states have unusual foaming properties among others. Aliphatic sulfonic amines and amides were prepared by I. G. Farben (97,98) in 1934 by reacting an alkyl halide with an amine and sulfonating and the amide by the reaction of an amine with the acid chloride of a sulfo acid. This type of amide was also patented in 1933 by Deutsche Hydrierwerke (99). Sandoz Ltd. (100) recently prepared an amide suitable for shampoos by reacting coconut oil with a chlorohydroxysulfonic acid and an alcohol derivative of ethylenediamine, which the patent states foams strongly. Dialkyl esters of aspartic acid were prepared in a patent to American Cyanamid Co. (101) in 1946. B. Harris (102) prepared interface modifying agents with the salts of 2-ethyl-1-hexanol sulfate. Hydroxy alkyl sulfonic acids with the hydroxyl group etherified were prepared in 1933 (103) and are particularly recommended for processes carried out at a low temperature. Similar ether sulfonic acids were patented in 1934 by H. Th. Bohme (104). Also, at this time sulfonic acids (105,106) were prepared by reacting an alkyl di- or trisulfonic acid with substances containing an OH group in the presence of a strong dehydrating agent.

Alcohols which are esterified with sulfuric acid show strong wetting and foaming properties. In patents to H. Th. Bohme, esters using starting materials such as hydroxylannic acid (107), stearyl alcohol or ricinoleic acid (108), or unsaturated hydrocarbons as centene (109) are sulfonated with sulfuric acid or chlorosulfonic acid. Weckert and Carter (110) prepared foaming agents from derivatives of 2-ethyl butyraldehyde by condensation with ketones, reduction of the ketones and sulfonation. In 1927 I. G. Farben (111) condensed saturated or unsaturated sulfuric esters of polyhydric alcohols with aromatic compounds such as naphthalene. Baldwin & Piggott (112) prepared sulfuric esters of hydroxy mercaptans from a compound such as 2-hydroxyethylcetylsulfide. The Deutsche Hydrierwerke (113) patented the compounds resulting from the esterification of glycols with one hydroxyl group esterified with sulfuric acid and the other hydroxyl group replaced by an amino radical. I. G. Farben in 1933 prepared sulfuric esters from ethanolamines or amides (114) and from glycol ethers and alcohols (115). H. Th. Bohme (116) also prepared sulfuric esters of hydroxy fatty amides. In a German patent (117), alcohols of 3 carbon atoms or more are polymerized and then sulfonated. In 1936, Snoddy & Martin (118)

reacted higher alcohols with the reaction product of SO_3 and a metal chloride. These were purported to be suitable for use in hard or sea water. The halogen ethers of higher alcohols are treated with sodium thiosulfate to produce the sulfuric esters of mercaptans as patented by Deutsche Hydrierwerke (119).

Henkel & Cie (120) prepared high molecular weight sulfur compounds such as the reaction product of dodecyl-mercaptan-1 and chloroacetic acid which they say has strong foaming properties. I. G. Farben (121) produced frothing chemicals by condensing a fatty acid amide, a tertiary amine, formaldehyde and sulfur dioxide. Similarly, H. Th. Bohme (122) prepared sulfuric esters of amides and anilides.

Recently, several sulfonamides or condensation products have been prepared with good foaming properties. In 1946, Ciba Ltd. (123) condensed sulfonamides with aldehydes or ketone bisulfite compounds, while in 1947, Albrecht for Ciba Ltd. (124) substituted fatty acids in the amido group, reporting production of a viscous mass of foam with this compound. I. G. Farben (125) in 1943 used unsubstituted sulfonamides as foam producers.

Products from the sulfonation of oils or petroleum fractions have been used as foaming agents. Such starting materials comprise cracked petroleum fractions (126), paraffin (127), purified glues (128), partially hydrogenated cottonseed or peanut oil or coconut oil (129), tall oil (130), and fish liver oil (131).

H. Th. Bohme has secured several patents on the sulfuric or phosphoric esters of sugar-like substances. These are prepared by reaction of dextrose (132,133) or grape sugar (134) with sulfuric or phosphoric acid and lauryl alcohol.

Hydrolyzed proteins are used as foaming agents in detergents and food industry in the following patents. I. G. Farben condenses chlorocarbonic esters with albumin degradation products (135), also gelatin (135) and chrome leather waste (136). Lenderink & Co. use vegetable or animal proteins such as pepsin (137).

Quaternary ammonium salts or cyclic and aliphatic compounds have been patented as foaming agents. In 1933, Ciba Ltd. (138) prepared compounds such as hydroxy ethyl pyridinium chloride with a fatty acid chloride. I. G. Farben (139,140) in 1934 and 1936 prepared similar compounds.

The following compounds cannot be placed in any special classification, being various organic molecules, and will be listed in groups by companies.

I. G. Farben has patented the following molecules: In 1930 (141) fatty acids were condensed with polyalkylene-polyamines, e.g. oleic acid with diethylene triamine. In 1934 (142), hydroxyamines were prepared by heating polyglycerol with a long chain aliphatic amine. Amino acids (143) from such chemicals as toluidine-5-sulfonic acid, formaldehyde and oleyl amide and carboxylic acids (144) from dicarboxylic acids and a hydrocarbon were patented in 1936. In 1943 two patents reacting lactones with phenols (145) and organic nitrogen compounds (146) were granted.

Ciba Ltd. in 1936 prepared an amine oxide (147), 8-octadecenylethyloyleclohexylamine by oxidizing the amine with a peroxide, which is stated to have strong capillary properties. In 1942 hydrazine derivatives (148), such as the product of reacting 1, 2-Bis (2-hydroxyethyl) hydrazine with stearic acid and then glycidol, were prepared. In very recent patents, amide derivatives were made by reacting a tertiary amine with formaldehyde and an amide (149), a new condensation product by reacting N,N -acetylstearyl-m-phenylenediamine and α, α -dichlorodimethylether with thiourea (150), and in 1949 the half esters of unsaturated dicarboxylic acids (151).

The Distillers Co. Ltd. (152) in 1934 prepared aldol condensation products and in the same year Henkel & Cie (153) produced high molecular weight amines such as B-hydroxy- α, α -bis (cyclohexylamino) propane and Chemische Fabrik (154) condensed sodium oleyate with bromotricarballic acid to improve foaming in soap. Products with saponaceous properties were prepared by Kirstahler and Kaiser (155) by the reaction of sodium thiosulfate on dodecylchloroacetic acid and like compounds, designated particularly as foaming agents in cosmetics and dentrifices.

Carbide and Carbon Corporation (156) prepared high molecular weight alcohols such as 5, 11-diethyl-8-pentadecanol along with the sulfate has strong frothing power. In a French patent 1936, (157) thio ethers are prepared reacting ethylene oxide with aliphatic mercaptans. J. R. Geigy (158) in 1942 made aliphatic ether derivatives of salicylic acids, such as 5-(octydecyloxymethyl)-2-hydroxy benzoic acid. S. Kaplan (159) prepared amino amide compounds by reacting an N-chloromethylamide with a tertiary amino acid amide.

In a recent patent to F. C. Bersworth Co. (160), 1950, compounds reported able to foam in any type of water were prepared by reacting such molecules as ethylenediamine with octyl chloride and then with chloroacetic acid. These are semi-solid pastes resembling stearic acid.

For inhibiting precipitation of soap in hard water, Young and Rubinstein (161) have prepared acylated alkylolamines by reacting primary and secondary alkylolamines with fatty acids.

In the flotation process, Powell (162) has prepared 1,1,3-trialkylloxybutanes, particularly 1,1,3-triethoxybutane as a frothing agent. Vana (163) has patented for du Pont, foaming agents for galvanizing fluxes, such compounds as pentaerythritol, ethyl trimethylolmethane, 2-amino-2-methyl-1,3-propandiol, etc.

Of particular interest are derivatives of citrus pectin prepared by J. F. Carson (164) which he reports produces very stable foams and are not precipitated by many metallic ions. The best derivatives reported were the propyl and butyl amides of polygalacturonide methyl ester. They are also insoluble in ethanol and ether.

R. C. Merrill (165) in 1948 discussed the addition of silicates to soaps for increasing the volume and stability of foam from a soap solution. He states that the addition of 0.1% of a 40° Baume 3.2 ratio silicate to a 0.1% sodium oleate solution increased the life of the foam more than tenfold.

In the same year, Harris (166) discussed the use of electrolyte builders for increasing foam volume. Maximum foam improvement resulted from monovalent cations, being reduced in volume by the divalent and trivalent cations.

Ordinary commercial soaps being unsuitable for use with sea water due to precipitation, various formulae have been prepared which would give a satisfactory foam in sea water.

As early as 1921, a British patent (167) uses potassium chlorite or other strong oxidizing agent with soap made from "cocoa oil". Peoh (168) in 1922 prepares a sea water soap from coconut oil, sodium hydroxide, sodium silicate and potassium chlorite. In a Japanese patent (169), red algae is used in soap made from palm oil, together with ammonium chloride and ammonium sulfate.

I. G. Farben (170) in 1935 used salts of amines or of quaternary ammonium bases containing alkyl radicals of high molecular weight, e.g. the hydrobromide salt of N-dimethyl dodecylamine is made into a soap with potato flow.

In a U. S. patent (171), olefins containing more than 7 carbon atoms, such as a product from oil cracking is sulfonated and is used as a soap for sea water.

A French patent (172) saponifies fat acids of molecular weight below 210 and mixed with high molecular weight fatty acids.

In a recent patent (173), naphthalene and lauryl alcohol is sulfonated and mixed with bentonite. This product is mixed with corn starch, anhydrous soap and water, and is reported to produce copious foam in even double strength sea water.

Rosin is used with tallow soap together with a phosphate to prepare a suitable salt water soap. Sodium resinate is mixed with 41° to 42° titer tallow soap followed by the addition of alkali salts. The sodium resinate used in one of the preparations was a spray-dried material sold under the trade name "Dresinate".

I. G. Farben (170) in 1935 used salts of amines or of quaternary ammonium bases containing alkyl radicals of high molecular weight, e.g. the hydrobromide salt of N-dimethyl dodecylamine is made into a soap with potato flow.

In a U. S. patent (171), olefins containing more than 7 carbon atoms, such as a product from oil cracking is sulfonated and is used as a soap for sea water.

A French patent (172) saponifies fat acids of molecular weight below 210 and mixed with high molecular weight fatty acids.

In a recent patent (173), naphthalene and lauryl alcohol is sulfonated and mixed with bentonite. This product is mixed with corn starch, anhydrous soap and water, and is reported to produce copious foam in even double strength sea water.

Rosin is used with tallow soap together with a phosphate to prepare a suitable salt water soap. Sodium resinate is mixed with 41° to 42° titer tallow soap followed by the addition of alkali salts. The sodium resinate used in one of the preparations was a spray-dried material sold under the trade name "Dresinate".

1. Erwin	U.S.	1,247,803
2. Van Leunen	U.S.	1,507,943
3. Phillips	Brit.	214,075
4. Ferguson	Can.	262,213
5. Ewer	U.S.	1,562,878
6. Esselen	U.S.	1,558,599
7. Sandor	Brit.	280,208
8. Excelsior Feuerlosch	Brit.	263,812
9. Berghausen Chemical Co.	U.S.	1,848,042
10.	U.S.	1,832,109
11. Urquhart	U.S.	1,922,510
12. Minimax	Fr.	764,138
13. Sthamer	U.S.	2,151,398
14. Fyr-Fyter Company	U.S.	1,973,734
15. Pyrene Minimax	U.S.	2,193,541
16. Pyrene Minimax	U.S.	2,196,042
17. Pyrene Company	Brit.	517,812
18. Standard Oil of California	U.S.	2,250,182
19.	Swiss	209,469
20. Urquhart	U.S.	2,269,958
21. Boyd	U.S.	2,269,426
22. Fyr-Fyter Company	U.S.	2,289,688
23. The Pyrene Company	Brit.	559,503
24. M & P Colloid Stabilizers	Brit.	560,354
25. Armour & Co.	U.S.	2,431,256

26.	Perri	U.S.	2,470,719
27.	Amer.-LaFrance-Foamite	U.S.	2,355,935
28.	Schnabel	U.S.	1,669,213
29.	Sthamer	U.S.	1,696,507
30.	Mauge	Fr.	796,615
31.	I. G. Farben	U.S.	2,154,231
32.	I. G. Farben	Ger.	668,276
33.	Pyrene Minimax	U.S.	2,361,057
34.	Pyrene Company	Brit.	517,767
35.	I. G. Farben	Ger.	681,158
36.	R. M. Hollingshead Corp.	U.S.	2,365,619
37.	Central Soya Company	U.S.	2,489,208
38.	Dawson	Brit.	Application
39.	Davies	Brit.	571,686
40.	Bohme Fettchemie	U.S.	2,136,963
41.	I. G. Farben	Ger.	697,646
42.	General Aniline & Film Co.	U.S.	2,232,053
43.	Amer.-LaFrance-Foamite	U.S.	2,405,538
44.	General Aniline Works	U.S.	1,914,406
45.	Brit. Dyestuffs Corp.	Brit.	289,630
46.	I. G. Farben	U.S.	2,165,997
47.	Meck & Elect. Teck.	Brit.	403,291
48.	I. G. Farben	Fr.	789,327
49.	H. Th. Bohme	Fr.	779,096
50.	I. G. Farben	Ger.	666,782

51. Henkel & Cie	Ger.	650,919
52. I. G. Farben	Fr.	716,560
53. I. G. Farben	Fr.	781,818
54. General Aniline & Film Corp.	U.S.	2,506,062
55. General Aniline & Film Corp.	U.S.	2,529,211
56. Burgess	U.S.	1,599,006
57. Texas Company	U.S.	2,166,008
58. A. G. Fur Technische Neuheiten	Swiss	259,609
59. Henkel & Cie	Fr.	790,831
60. Henkel & Cie	Fr.	788,748
61. Grinnel Corp.	U.S.	2,487,964
62. I. G. Farben	Ger.	539,150
63. du Pont	U.S.	2,476,308
64. Pyrene Company	Brit.	580,070
65. Pyrene Development Corp.	Can.	435,733
66. Johnson & Adams Standard Oil of Indiana	U.S.	2,429,691
67. I. G. Farben	Ger.	518,408
68. Gilbert & Otto Allied Chemical & Dye Co.	U.S.	2,506,417
69. Deutsche Hydrierwerke	Brit.	417,394
70. Henkel & Cie	Fr.	790,626
71. I. G. Farben	Ger.	551,257
72. Deutsche Hydrierwerke	Fr.	753,753
73. Soc. pour l'ind chim a Bale	Brit.	582,092
74. L. H. Flett	Brit.	447,898

75.	I. G. Farben	Brit.	302,666
76.	Henkel & Cie	U.S.	2,007,869
77.	Henkel & Cie	Ger.	623,919
78.	Imperial Chemical Industries	Brit.	443,902
79.	I. G. Farben	Fr.	788,429
80.	I. G. Farben	Brit.	248,782
81.	I. G. Farben	U.S.	1,732,503
82.	H. Th. Bohme	Ger.	565,056
83.	H. Th. Bohme	Fr.	685,995
84.	Soc. pour l'ind chim a Bale	Swiss	177,818
85.	Soc. pour l'ind chim a Bale	Swiss	190,717
86.	Soc. pour l'ind chim a Bale	Swiss	221,824
87.	Soc. pour l'ind chim a Bale	Swiss	222,543
88.	Jiri Polasek	Fr.	940,117
89.	J. R. Caldwell Eastman-Kodak Co.	U.S.	2,478,368
90.	I. G. Farben	Brit.	372,005
91.	I. G. Farben Daimler et al.	U.S.	1,881,172
92.	I. G. Farben Daimler et al.	U.S.	1,916,776
93.	Ciba Ltd.	Swiss	238,442
94.	J. R. Geigy A.G.	Swiss	160,079-80-1
95.	B. Harris	U.S.	2,023,387
96.	J. Ross Colgate-Palmolive-Peet	U.S.	2,420,383
97.	I. G. Farben	U.S.	1,944,300
98.	I. G. Farben	U.S.	1,931,540

99.	Deutsche Hydrierwerke	Fr.	750,647
100.	Sandoz Ltd.	Swiss	261,540
101.	American Cyanamid	Brit.	575,608
102.	B. Harris	U.S.	2,052,027
103.	Deutsche Hydrierwerke	Fr.	752,756
104.	H. Th. Bohme	U.S.	1,967,655
105.	Flesch-Werke	Brit.	406,889
106.	Bohme Fettchemie	Ger.	627,055
107.	H. Th. Bohme	Ger.	546,142
108.	H. Th. Bohme	U.S.	1,993,431
109.	Bertsch H. Th. Bohme	U.S.	2,027,896
110.	Weckert & Carter Carbide and Carbon	Brit.	446,084
111.	I. G. Farben	Ger.	526,276
112.	Baldwin & Piggott Imperial Chemical Industries	Brit.	435,039
113.	Deutsche Hydrierwerke	Brit.	435,290
114.	I. G. Farben	Brit.	389,543
115.	I. G. Farben	Brit.	394,043
116.	H. Th. Bohme	Ger.	595,173
117.	Chem. Fab. Pott & Co.	Ger.	550,242
118.	Snoddy & Martin Proctor & Gamble	U.S.	2,049,670
119.	Deutsche Hydrierwerke	Brit.	390,416
120.	Henkel & Cie	U.S.	2,050,169
121.	I. G. Farben	Fr.	799,093

122.	H. Th. Bohme	Brit.	318,542
123.	Ciba Ltd.	Brit.	578,654
124.	Albrecht-Ciba Ltd.	U.S.	2,432,850
125.	I. G. Farben	Belg.	449,444
126.	H. Th. Bohme	Brit.	360,602
127.	I. G. Farben	Brit.	366,916
128.	Imperial Chemical Industries	Brit.	469,325
129.	B. Harris	U.S.	2,029,168
130.	H. Th. Bohme	Ger.	596,510
131.	Imperial Chemical Industries	Brit.	398,818
132.	H. Th. Bohme	Brit.	384,230
133.	H. Th. Bohme	Brit.	404,684
134.	H. Th. Bohme	Ger.	606,897
135.	I. G. Farben	Brit.	425,370
136.	I. G. Farben	Brit.	450,407
137.	Lenderink & Co.	Dutch	65,195
138.	Ciba Ltd.	Brit.	388,840
139.	I. G. Farben	Brit.	414,712
140.	I. G. Farben	Brit.	448,251
141.	I. G. Farben	Brit.	337,368
142.	I. G. Farben	Ger.	606,236
143.	I. G. Farben	Fr.	799,910
144.	I. G. Farben	Brit.	449,865
145.	I. G. Farben	Belg.	450,233
146.	I. G. Farben	Belg.	450,587

147.	Ciba Ltd.	Swiss	180,579-81
148.	Ciba Ltd.	Swiss	223,211
149.	Ciba Ltd.	Brit.	600,707
150.	Ciba Ltd.	Swiss	219,858
151.	Ciba Ltd.	Brit.	615,665
152.	The Distillers Co. Ltd.	Brit.	411,483
153.	Henkel & Cie	Fr.	774,087
154.	N. V. Chemische Fabrik	Brit.	420,812
155.	Kirstahler and Kaiser	U.S.	2,004,873
156.	Carbide and Carbon	Fr.	789,406
157.		Fr.	794,830
158.	J. R. Geigy A.G.	Swiss	219,930
159.	S. Kaplan Onyx Oil & Chemical Co.	U.S.	2,407,703
160.	F. O. Bersworth Co.	U.S.	2,524,218
161.	Young and Rubinstein Industrial Patent Corp.	U.S.	2,429,445
162.	R. F. Powell National Chemical Products Ltd.	Brit.	641,932
163.	C. Vana E. I. du Pont de Nemours	U.S.	2,481,457
164.	J. F. Carson - J. American Chem. Soc.	<u>68</u>	2723 (1946)
165.	R. O. Merrill - J. American Oil Chemist Soc.	<u>25</u>	84 (1948)
166.	J. O. Harris - American Dyestuff Reporter	<u>37</u>	266 (1948)
167.		Brit.	156,591
168.	Pech	U.S.	1,462,243

169.	Japan	42,569
170. I. G. Farben	Fr.	780,044
171.	U. S.	2,049,055
172.	Fr.	48,182
173. Kamen Soap Products Co.	U. S.	2,407,130
174. Oil and Soap	<u>21</u> 164	(1944)
175. Hercules Powder Co.	U.S.	2,402,473

EXPERIMENTAL

1. Foams made from solutions of soaps, alkyl aryl sulfonates, alcohol sulfates, proteins and saponins were evaluated and found wanting from standpoint of stability toward ethyl alcohol. Pectin and algin derivatives were also investigated with negative results.

2. The quaternary ammonium compounds showed most promise for use with sea water. The following were prepared in this series:

Octyl benzyldimethyl ammonium bromide
Octyl pyridinium bromide
Lauroyl benzyldimethyl ammonium chloride
Lauroyl pyridinium chloride
Phenyl diethyl alkyl ammonium bromide
Octyl triethyl ammonium bromide
Phenyl dimethyl alkyl ammonium bromide
Phenyl dimethyl octyl ammonium bromide
Phenyl diethyl octyl ammonium bromide
Alkyl quinolinium bromide
Octyl quinolinium bromide
Diethyl octyl ethanol ammonium bromide
Hydroxyethyl pyridinium chloride
Dioctyl nicotinium bromide
Octadecyl nicotinium chloride
Octadecyl octyl nicotinium chloride

Di (hydroxyethyl) phenyl octyl ammonium bromide
Octadecyl pyridinium chloride
Hydroxyethyl phenyl ethyl octyl ammonium bromide
Octadecyl benzyl dimethyl ammonium chloride
Lauryl pyridinium chloride
Decyl pyridinium chloride
Octyl picolinium bromide
Nonyl pyridinium chloride
Butyl pyridinium bromide

3. Lauryl pyridinium chloride was found effective in salt water and was further tested with materials which would be likely to confer alcohol stability on foam derived from same. Lauryl pyridinium stearate and related materials serve satisfactorily in this respect.

Homologous series of alkyl pyridinium chlorides and bromides were prepared covering the range propyl to decyl for each halide. Decyl pyridinium chloride and bromide were the only ones in the series that were good foaming agents in themselves. They were then used in conjunction with lauryl pyridinium chloride to test for synergistic action. The best one in this respect was octyl pyridinium bromide. Lauryl pyridinium stearate used as a stabilizer as previously reported, was insoluble in the pyridinium halide.

4. The lauryl ester of carboxymethyl pyridinium chloride was prepared which gave an expansion of ten in a 1% sea water solution, but exhibited no alcohol stability. The octadecyl and tetradecyl esters were also prepared but with no improvement in alcohol stability. Pyridinium esters with a free carboxyl group were prepared, e.g. carboxymethyl pyridinium stearate, which when used as a stabilizer with lauryl pyridinium chloride reduced the expansion but showed very good alcohol stability.

5. From unpublished work previously done in this laboratory it was known that compounds of this type when converted to

the aluminum salt exhibited a marked stabilizing effect. The aluminum salt was prepared by inclusion of an aqueous solution of aluminum lactate in formulae containing these stabilizers. The stabilizers showing the greatest promise were carboxymethyl pyridinium stearate and carboxymethyl benzyldimethyl ammonium stearate.

These principles were applied in the following formulation which showed good alcohol stability, an expansion of ten in sea water and freezing point of approximately 20° F.

20 cc methyl alcohol
15 g. lauryl pyridinium chloride
4 cc octyl pyridinium bromide
2.5 g. carboxymethyl pyridinium stearate
3.0 g. aluminum lactate
1.06 cc triethanolamine
0.5 g. lauryl pyridinium stearate
6 cc chloroform
q.s. 100 cc water

Fire tests conducted on isopropyl alcohol were unsuccessful demonstrating in the main that the foam lacked heat resistance.

6. Heat resistance improvement can be effected by the incorporation of hydrolyzed protein material. Systems comprised of the following ingredients were then studied in conjunction with quaternary ammonium compounds:

Hydrolyzed protein

Fatty acids

Iron sulfate

7. A foam having an expansion factor of ten was obtained using a 6% solution in sea water. These materials combined in proper proportions yield a foam having the necessary alcohol and heat resistance. The foam liquid concentrate was not entirely homogeneous.

8. The simple addition of fatty acid soaps to the product of a lime hydrolysis of protein results in formation of a precipitate of calcium soaps. The calcium may be readily sequestered by the use of ethylene diamine tetra acetic acid to produce a clear solution. Alcohol stability of the foam from such a liquid, however, is greatly reduced.

9. Investigation of fatty and hydroxy-fatty acids indicated that the more soluble the soap, the less effective was its alcohol-foam stabilizing effect.

Aluminum lactate proved to be the best cation-furnishing salt amongst the bi- and trivalent metallic ions tried.

Not much difference could be found between the use of animal and vegetable proteins.

10. A foam liquid based upon these findings was manufactured on pilot plant scale. It contained:-

Hydrolyzed blood

Coconut fatty acids

Aluminum lactate

Propylene glycol

Chloroform

The chloroform was used as a solubilizing agent for the aluminum soaps formed in situ. The chloroform, however, affected the foam volume adversely, an expansion of five being obtained.

Fire tests were conducted on 25-gallon quantities of isopropyl alcohol and a pan having dimensions 5.5 ft. x 5.5 ft. x 1 ft. The results are tabulated.

Type Alcohol	Ethyl	Isopropyl	Isopropyl
Rate of Application (gal. water/sq. ft./min.)	1	2	1
Preburn Time (min.)	1	1	1
Control Time	40 sec.	48 sec.	1 m. 36 sec.
Extinguishment Time	50 sec.	1 m. 4 sec.	1 m. 57 sec.

11. Zinc chloride was found to improve the foam expansion of this formulation, an expansion of 9 being obtained. On the other hand, however, zinc chloride causes a decrease in fluidity and in alcohol stability.

12. Stearic acid has the effect of increasing alcohol stability and decreasing foam volume. Zinc chloride in combination with stearic acid does not affect foam volume.

13. The fatty acids used as described do not have the desired solution stability, and it is necessary to add another agent to prevent their deposition. Alkyl aryl sulfonates have been found to behave as satisfactory solubilizers. The first of this class of materials that was investigated was sodium xylene sulfonate.

Pilot plant batches of foam liquid using sodium xylene sulfonate as solubilizer for 7% coconut fatty acid were prepared and are described in terms of Specifications tests. The Air Force Specifications are expressed parenthetically.

Air Force Specifications

3. Chemical Properties

a. Specific Gravity	1.162	(No restrictions have been placed on the contractor as to this value.)
b. Viscosity	25 cent. @ 60°F.	(Maximum viscosity of 100 centistokes at 60°F.)
c. pH Value	6.2	(6.0 - 9.0)

d. Suitability with Water

- (1) Expansions of 10 have been obtained using either fresh or synthetic sea water through a National RP-3 nozzle at 70°F. and 100 psi.
- (2) Ethyl alcohol fire tests conducted in a 30 sq.ft. pan have shown that foam is equally effective using fresh water or synthetic sea water.

e. Pour Point 10°F.

Although the pour point is 10°F. the liquid has the characteristics of depositing crystals on storage at 20°F. for a period of 48 hours.

f. Sedimentation Trace (0.1% max.)

g. Precipitation Max. 1% (No minimum is given. "Good fire fighting engineering and chemical practices shall endeavor to limit precipitation to a minimum when the liquid charge is mixed with water.")

4. Environmental Extremes

Evaluation in this respect was not completed.

5. Foam Volume

- a. 140 gallons of foam per gallon liquid obtained under the following conditions:

- (1) National RP-3 nozzle, 100 psi, 70°F. liquid and fresh water temperatures.

- (2) National RP-3 nozzle, 100 psi, 70°F. liquid and synthetic sea water.
- (3) Further evaluation being conducted using the Navy NPU nozzle with fresh and salt water at various temperatures.

6. Dispensing Equipment

Field tests had been conducted using standard National foam nozzles.

7. Fire Tests

a. 30 sq. ft. test pan

It is our standard practice to evaluate untested foam liquids on fires of a limited size. The rate of water application in these tests is 0.1 gpm per sq. ft. Gasoline and ethyl alcohol fires have been extinguished in what is considered standard time for this type test.

b. JAN C-266 - 10 ft. x 10 ft. fire test

- (1) Gasoline Fire -- The rate of water application in this test is 0.06 gpm per sq. ft. The fire was extinguished in 2 minutes and 55 seconds. The blanket thickness was 3 inches. Further evaluation concerning the blanket characteristics remains to be done.

14. Fire testing was continued on the liquid charge described. An alcohol fire test was successfully run in a 30 sq. ft. test pan using a water application rate of 0.1 gpm per sq. ft., provision being made for gentle foam application.

The JAN C-266 fire test requirement presents a more severe fire test condition in that the foam stream is directed through the fire on to a backboard. As a result of forceful impingement of the foam stream on the backboard, the foam is subjected to a considerable amount of submersion in the alcohol.

Hence, a higher rate of application is necessary for extinguishment than would apply in the case of gentle application. The following table summarizes results obtained for various rates and methods of application.

JAN C-266 FIRE TEST DATA

Rate Water-in-Foam Application (gpm/sq.ft.)	Cover	Control	Extinguishment	* Type Appli- cation
0.06	(No extinguishment obtained)			a
0.06	20 seconds	1 min., 5 sec.	1 min., 25 sec.	b
0.15	1 min., 30 sec.	1 min., 45 sec.	2 minutes	a
0.20	30 seconds	1 minute	1 min., 30 sec.	a

* a -- Foam stream directed against backboard of test tank.

b -- Foam stream directed into corner of test tank, force of impingement into alcohol lessened.

A pilot plant batch of this material was made with some processing modifications. An ethyl alcohol fire was extinguished at a water-in-foam rate of 0.06 gpm per sq. ft. using "a" type application.

15. Attempts to reduce freezing point of this material included investigation of:-

1. Isopropyl alcohol content
2. Glycol content
3. Water content
4. Use of propylene glycol
5. Use of zinc acetate in place of aluminum lactate
6. "Wetsit" as solubilizer

Freezing point characteristics were improved by increasing water content of the liquid. A pilot plant batch was made based upon the finding reported. The higher water content resulted in a material showing no signs of freezing on storage at 20°F. The other significant characteristics were not materially affected.

Investigation into use of the glycols and alcohols as freezing point depressants indicated that relatively high concentrations of methanol work to advantage. Representative fire test data for this type liquid are given below.

Rate Water-in-Foam Application (gpm/sq.ft.)	Type Alcohol Fire	Extinguishment Time	Type Application (see 14)
0.07	Isopropyl	1 min., 45 sec.	a
.11	Isopropyl	58 seconds	a
.11	Ethyl	1 minute	a

16. The foam liquid developed under this contract is described below. The contract Specifications for each characteristic is given first, the corresponding description of the foam liquid follows in the indented script.

DETAILED REQUIREMENTS, EXHIBIT

1. Material

a. The mechanical foam charge shall be a liquid containing stabilizers, preservatives, or such other material as the contractors deem desirable to attain a foam suitable for ethyl alcohol and petroleum fires.

1. Material

a. The mechanical foam charge is a liquid containing stabilizers, preservatives, and such other material as is necessary to obtain a foam suitable for ethyl alcohol and petroleum fires.

2. Foam Characteristics

a. When mixed with air and water, in proportions to be determined by the contractor, the charge shall produce a stable, cohesive foam of satisfactory degree of fluidity for extinguishing petroleum and ethyl alcohol fires. The foam produced shall consist of a mass of small bubbles not easily broken down by intense heat, shall adhere to solid surfaces whether vertical or horizontal, float on petroleum products and alcohol, shall not seriously injure personnel or equipment, shall not be toxic nor irritating to the skin and shall not be unduly corrosive to iron and steel.

2. Foam Characteristics

a. When mixed with water to form a 6% solution and used in conjunction with a standard foam nozzle, this charge produces a stable, cohesive foam of satisfactory degree of fluidity for extinguishment of petroleum and ethyl alcohol fires. The foam produced consists of a mass of small bubbles not easily broken down by intense heat, and adheres to vertical and horizontal solid surfaces. The charge or foam made therefrom is non-injurious to personnel or equipment, is non-toxic, not irritating to the skin, and not unduly corrosive to iron and steel.

3. Chemical Properties

a. Specific Gravity

(1) Specific gravity of the foam shall be determined but no restrictions are placed on the contractor as to its value.

(a) Specific Gravity

(1) The specific gravity of the foam charge is 1.150 - 1.160 at 70°F.

b. Viscosity

(1) The liquid shall have a maximum kinematic viscosity of 100 centistokes at 60°F.

b. Viscosity

- (1) The liquid has a kinematic viscosity of 25 centistokes at 60°F.

c. pH Value

- (1) The liquid shall have a pH value of 6.0 to 9.0 and shall not vary from this range upon the dilution up to the required amount of foam liquid in water.

c. pH Value

- (1) The pH value of the liquid is 6.2 and does not vary outside of the range 6-9 upon dilution with fresh or sea water.

d. Suitability with Water

- (1) The foam liquid shall form suitable foam with water irrespective of geographical location. Suitability with sea water is desirable to increase the utility of the liquid charge for the potential use by other Government agencies.

d. Suitability with Water

- (1) The foam liquid forms suitable foam with natural water irrespective geographic location. It has been found suitable for use with sea water, foam volume and fire test data supporting this statement.

e. Pour Point

- (1) The liquid shall have a pour point not higher than -20°F.

e. Pour Point

- (1) The pour point is -15°F. The liquid is completely miscible with ethylene

glycol and further pour point reduction can be achieved by simple admixture. A slight loss in foam quality would be expected.

f. Sedimentation

- (1) Charges shall show a sedimentation of not more than .1 per cent by volume.

f. Sedimentation

- (1) The charge shows only a trace of sediment formation.

g. Precipitation

- (1) Good fire fighting, engineering and chemical practices shall endeavor to limit precipitation to a minimum when the liquid charge is mixed with water.

g. Precipitation

- (1) Precipitate formation has been limited to minimum consistent with good foam production.

4. Environmental Extremes

a. The liquid charge shall not be impaired by storage for 72 hours at +160°F. or -65°F. Though the liquid may freeze, upon thawing it shall form foam with the same desirable characteristics as a sample not subjected to environmental extremes.

4. Environmental Extremes

- a. The liquid charge is not impaired by storage for 72 hours at 160°F. or -65°F. Although the liquid freezes, upon thawing it forms foam with the same characteristics as a sample not subjected to environmental extremes.

5. Foam Volume

a. The volume of foam produced by the liquid using water at 70°F. shall not be less than 125 gallons of foam per gallon of foam liquid used. The volume of foam produced at 40°F. shall not decrease more than 15% of the volume at 70°F.

5. Foam Volume

a. The volume of the foam produced by liquid using water at 70°F. was 140 gallons of foam per gallon of foam liquid. A National RP-3 nozzle operating at 100 psi was used. The volume of foam produced at 40°F. was less, to the extent of 10%, than the volume produced at 70°F. Approximately the same foam yields are obtained using either fresh or synthetic sea water.

6. Dispensing Equipment

a. It is most desirable that the foam developed under the requirements of this Exhibit be suitable for use with present mechanical foam equipment. If, however, the formulation of the All Purpose Foam should require special equipment or changes in design of present equipment, full information, design drawings and operating characteristics shall be reported.

6. Dispensing Equipment

a. The foam charge developed is suitable for use with present mechanical foam nozzles.

7. The liquid after subjection to conditions of environmental extreme shall, when tested in accordance with procedures of Specification JAN C-266, attain complete extinguishment in 5 minutes or less. The foam blanket shall average not less than 1 inch in thickness and shall prevent re-ignition for 15 minutes. Rekindling shall prevent spread of the fire beyond an area approximately 24 inches square. Fire tests shall be performed on both alcohol and petroleum fires.

7. The liquid after subjection to conditions of environmental extreme when tested in accordance with Specification JAN C-266 for gasoline fires and a modified fire test (see 14, type b application) to suit the special case of alcohol, accom-

plished extinguishment in less than 5 minutes. The foam blanket averages 3 inches in thickness and prevents re-ignition for 15 minutes. A 6-inch square of fuel surface was exposed and ignited. On permitting to burn for 5 minutes, the foam blanket resisted the spread of the fire beyond an area approximately 24 inches square.

1

MANUFACTURING PROCEDURES

Procedure for Manufacture of Mechanical Foam Liquid Developed Under this Contract.

Protein Isolation. Heat 260 gallons of water to 120°F. and add 150 pounds of oil-free soybean flour. After stirring for 1 hour, add sulfuric acid to bring mixture to a pH of 4.0-4.3. The mixture is passed through a centrifuge and the slurry is returned to a reactor together with 80 gallons of boiling water. Make up to 220 gallons with water if necessary.

Hydrolysis. The batch is heated to 200°F. and 30 pounds of lime is added. More lime is added if necessary to keep pH up to 11.8. Maintain heat at 200°F. for five hours. Add sulfuric acid to reduce the pH to 4.0-4.5. Heat at this pH for 1 hour at 200°F. The pH is then raised to 7.0-7.5 with lime.

Evaporation. Evaporate the mixture to a specific gravity of 1.185 at 60°F.

Adjustment. The following chemicals are then added to the concentrate:

pyridyl mercuric acetate	0.3 lb./100 gallons
sodium sulfate	0.33 lb./gallon
ferrous sulfate	0.40 lb./gallon

Blending. The liquid is allowed to stand for 2 hours and the following additions are made:

urea	0.8 lb./gallon
equal mixture of isopropyl alcohol and ethylene glycol	17.6 gal./100 gallons

Filter with aid of Celite.

Conversion. Seventy gallons of this liquid is placed in a reactor and the following chemicals are added with stirring.

100 lbs. Sodium diisopropyl naphthalene sulfonate
9.8 gals. Water
30 lbs. Aluminum Lactate
12 gals. Methanol
2.88 gals. Coconut fatty acid
2.16 gals. Triethanolamine

Add Celite to the mixture and filter through a precoated filter press. The filtrate is returned to the reactor and the following are added.

12.6 lbs. Aluminum lactate
1.44 gals. Coconut fatty acid
1.08 gals. Triethanolamine
18 gals. Ethylene Glycol

Stir the mixture for 2 hours and allow to stand overnight. The batch is filtered through a precoated filter press.

ALTERNATE PROCEDURE

Isolated soybean protein is available on the market from Drackett Corp. as "Ortho Protein", from The Glidden Corp. as "Alpha Protein" and from Buckeye Cotton Oil Co. as "Buckeye Protein". The use of one of these materials eliminates the "Protein Isolation" step and starts with the hydrolysis directly. In that case, add 225 pounds of the protein as purchased to 250 gallons water at 200°F. Add 50 pounds of lime and heat at 200°F. for five hours. Add sulfuric acid to reduce pH to 4.0-4.5. Heat one hour further. Add sufficient lime to raise pH to 7.0-7.5. Evaporate and continue as in first procedure.

SURFACE TENSION STUDIES

1. The surface tension characteristics of three foam liquids were established.

- a. National Aer-O-Foam liquid. This is a hydrolyzed protein-base foam liquid which conforms to specifications JAN C-266.
- b. National Aer-O-Foam 99. A commercial foam liquid used in combat of fires involving alcohols as well as petroleum products. Fatty acids are used as the foaming agent base and stabilizer. It has the limitation that it cannot be used effectively with water having a hardness in excess of 400 p.p.m.
- c. AAF 116. This is one of the experimental liquids developed under subject contract. It contains the essential ingredients of "a" and "b", modified to achieve compatibility, and produces a foam which is not readily destroyed by alcohol.

2. The effect of the addition of water on surface tension of the three foam liquids. Figure I

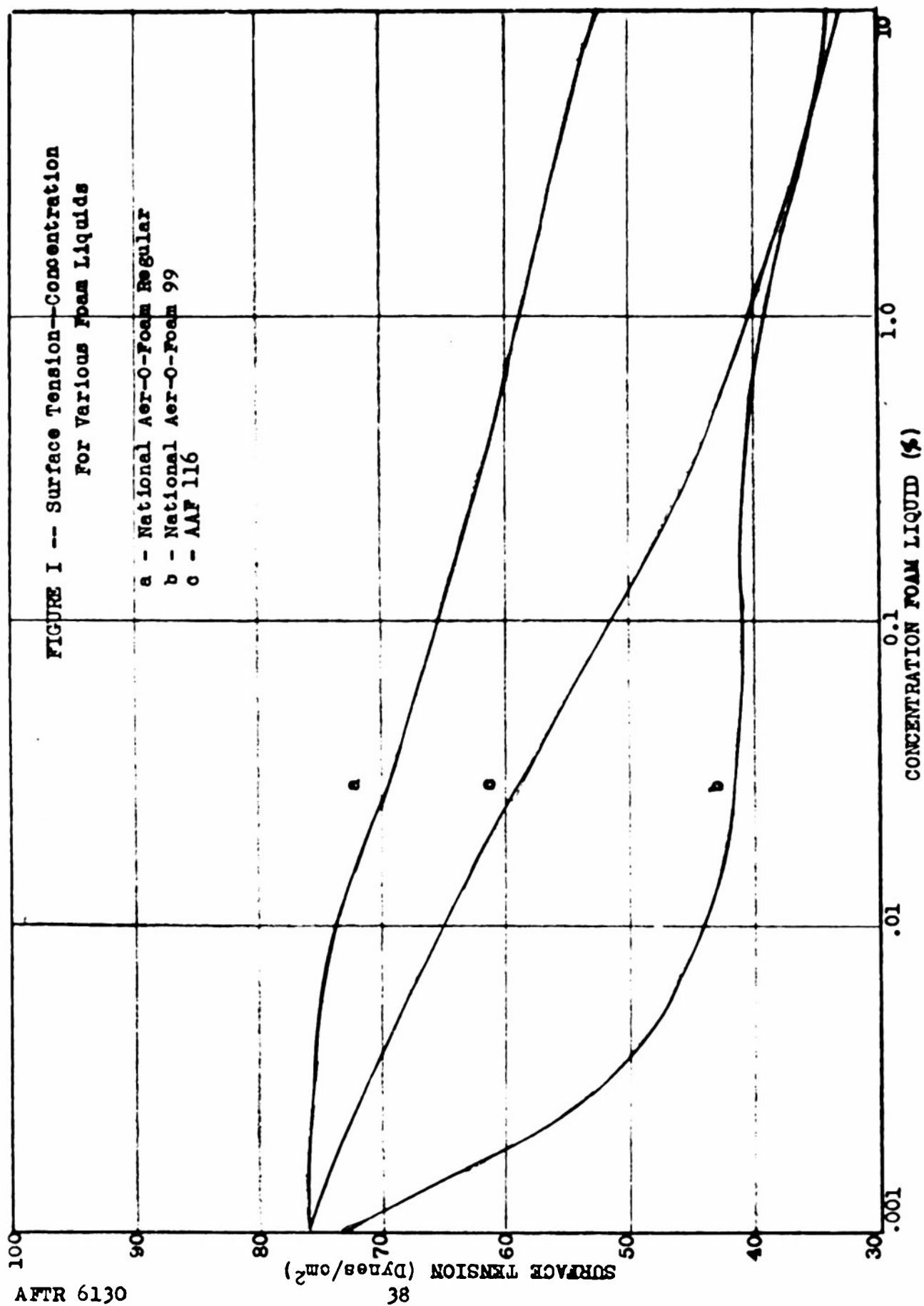
3. Effect of Aging on Aer-O-Foam 99 Solutions

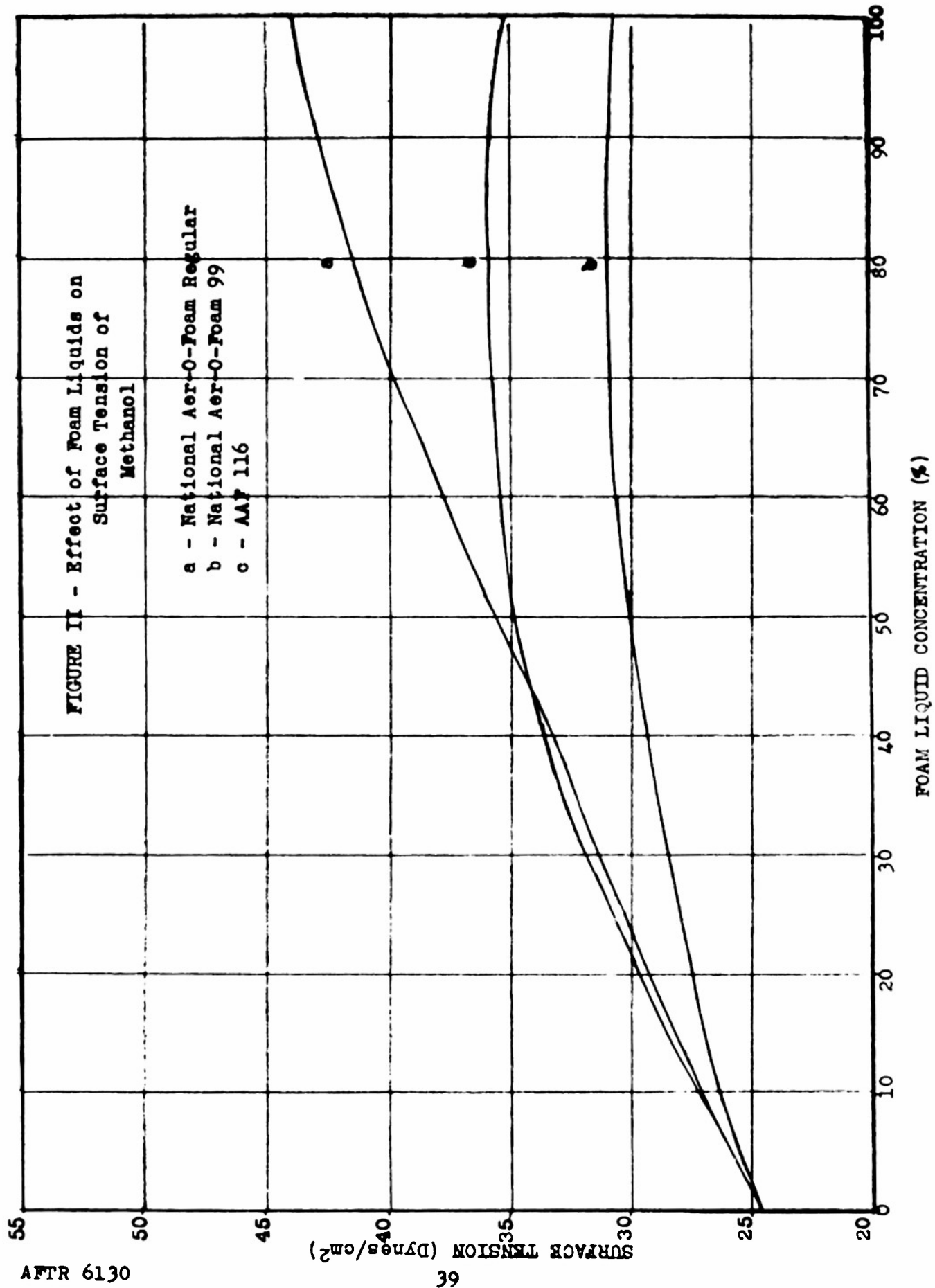
Solutions of Aer-O-Foam 99 in the concentration range 0.005 - 6.0% were aged up to four days and measurements taken periodically. Each solution showed no change in surface tension due to aging of the solutions.

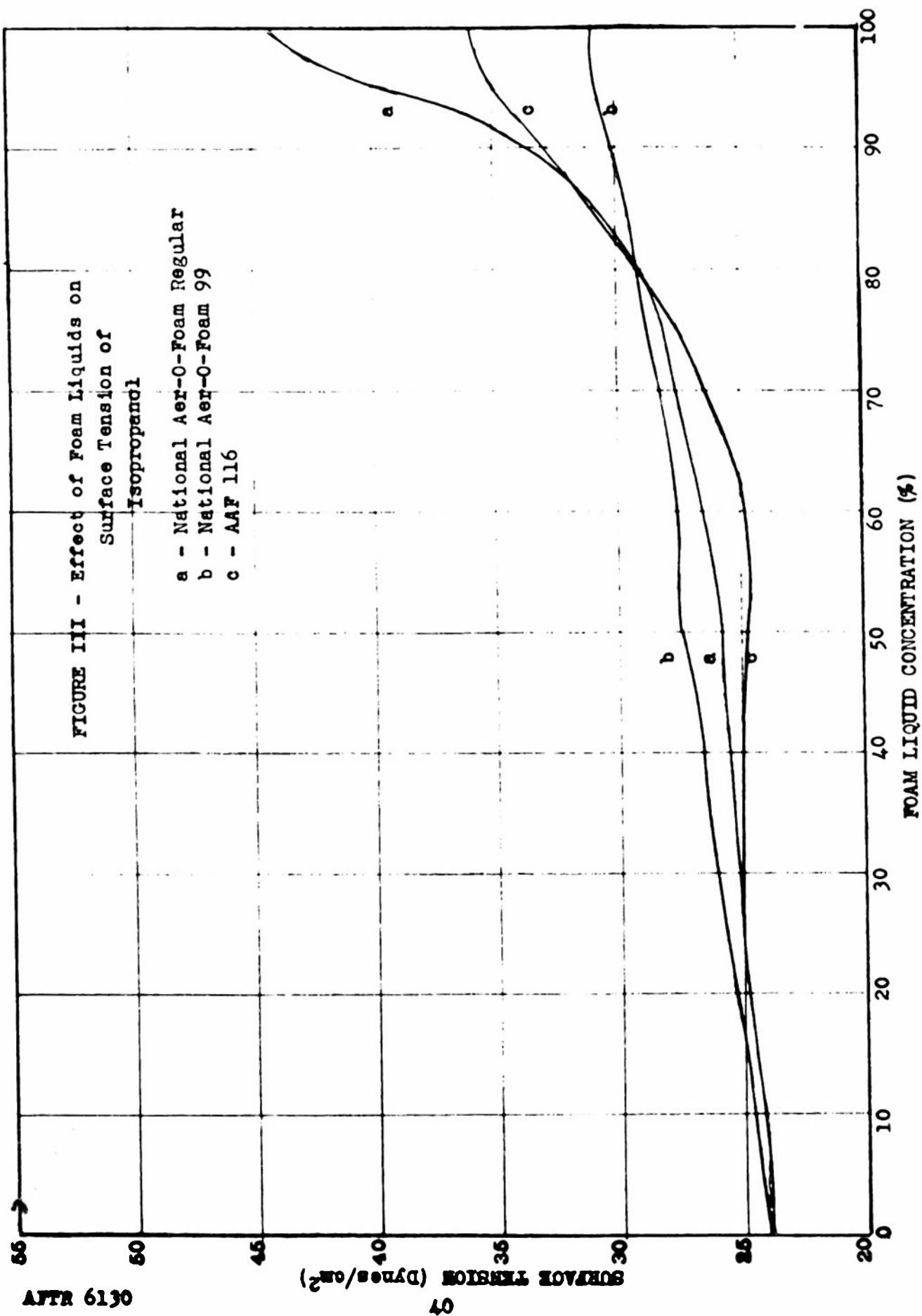
4. The effect of the three foam liquids on the surface tension of methanol. Figure II

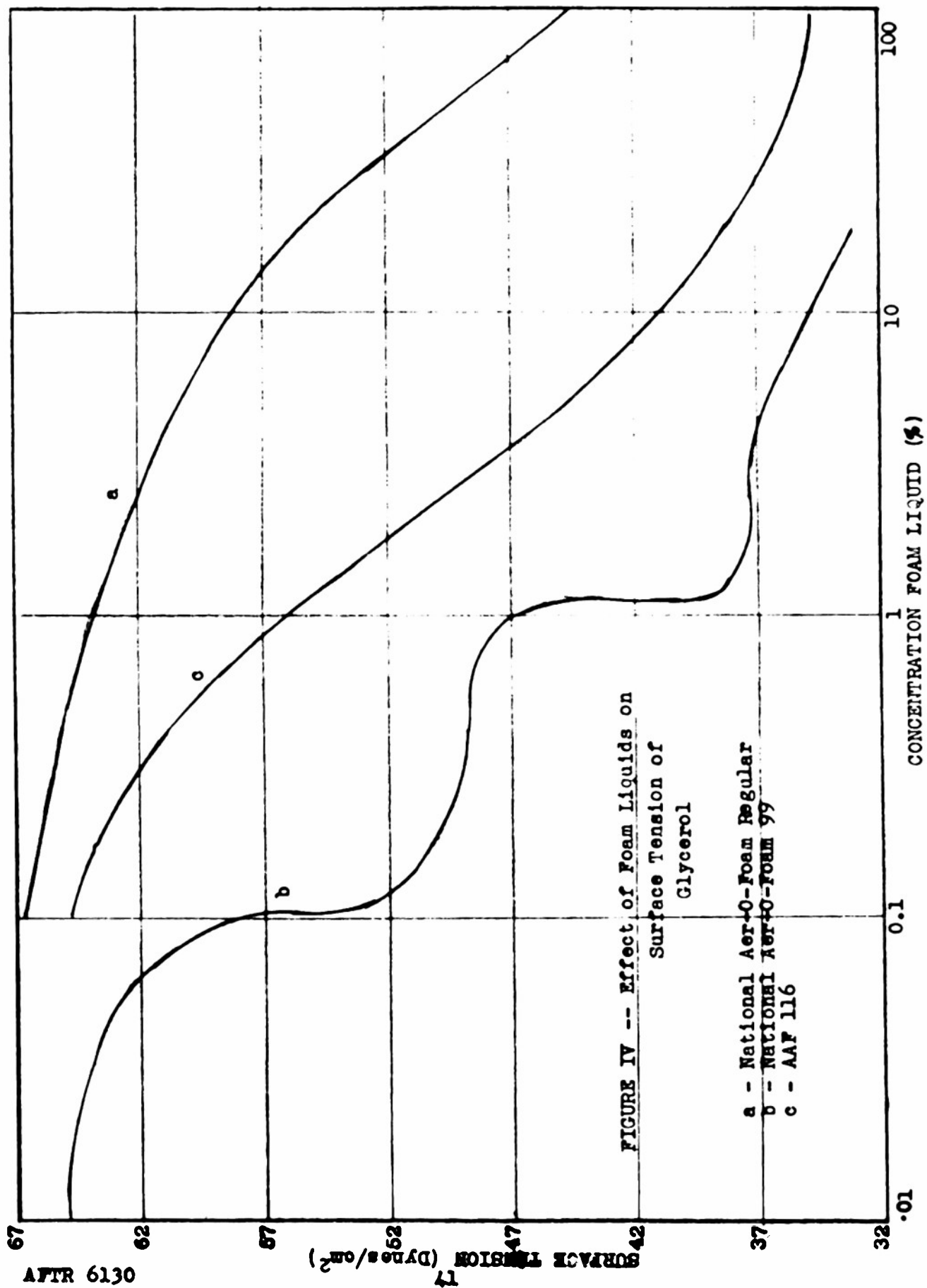
5. The effect of the three foam liquids on the surface tension of isopropanol. Figure III

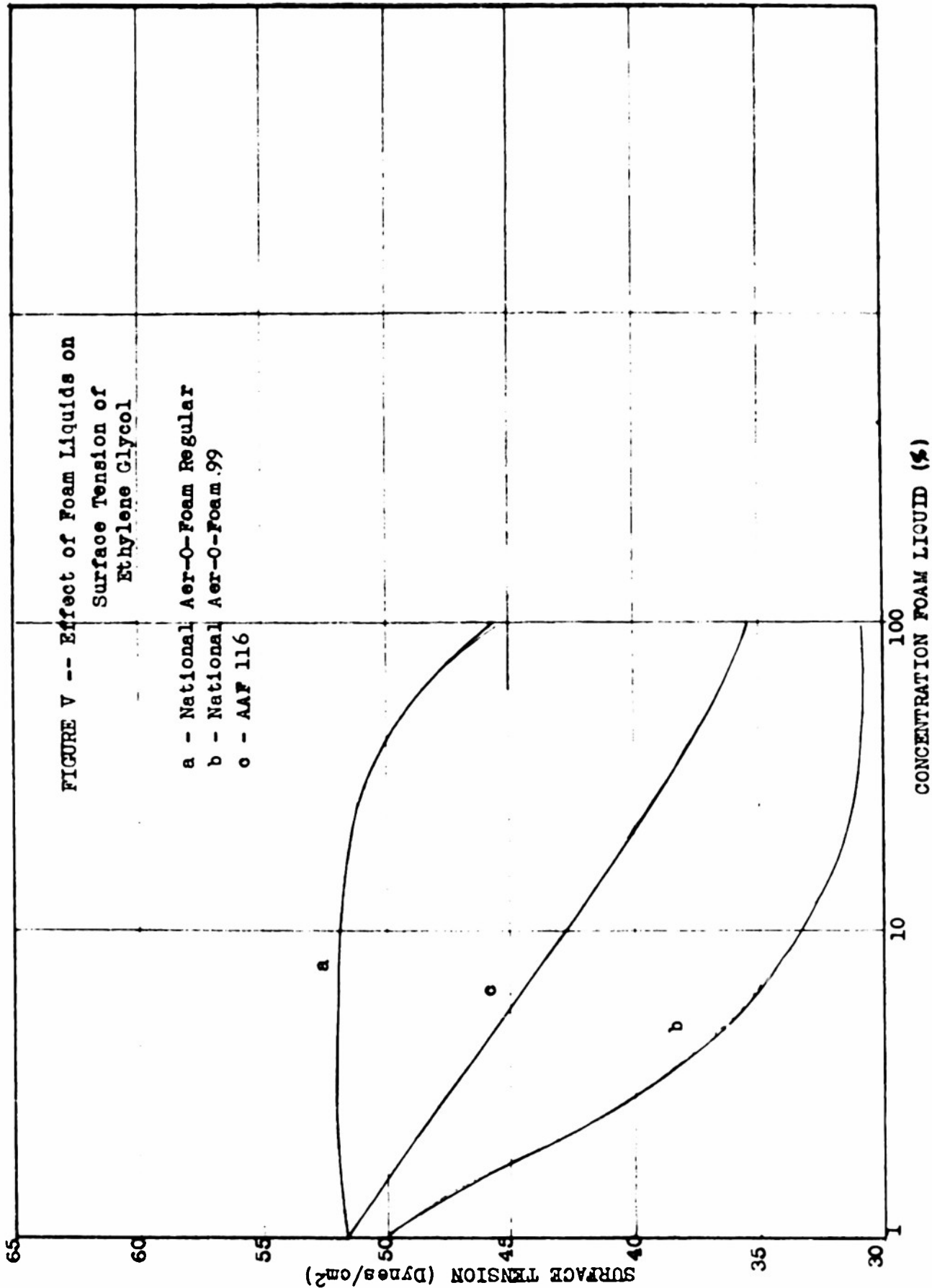
6. The effect of the three foam liquids on surface tension of glycerol. Figure IV
7. The effect of three foam liquids on the surface tension of ethylene glycol. Figure V
8. The effect of Aer-O-Foam 99 on surface tension of various alcohols. Figure VI
9. The effect of AAF 116 on surface tension of various alcohols. Figure VII
10. The effect of Regular Aer-O-Foam on surface tension of some alcohols. Figure VIII
11. The effect of three foam liquids on surface tension of Formamide. Figure IX











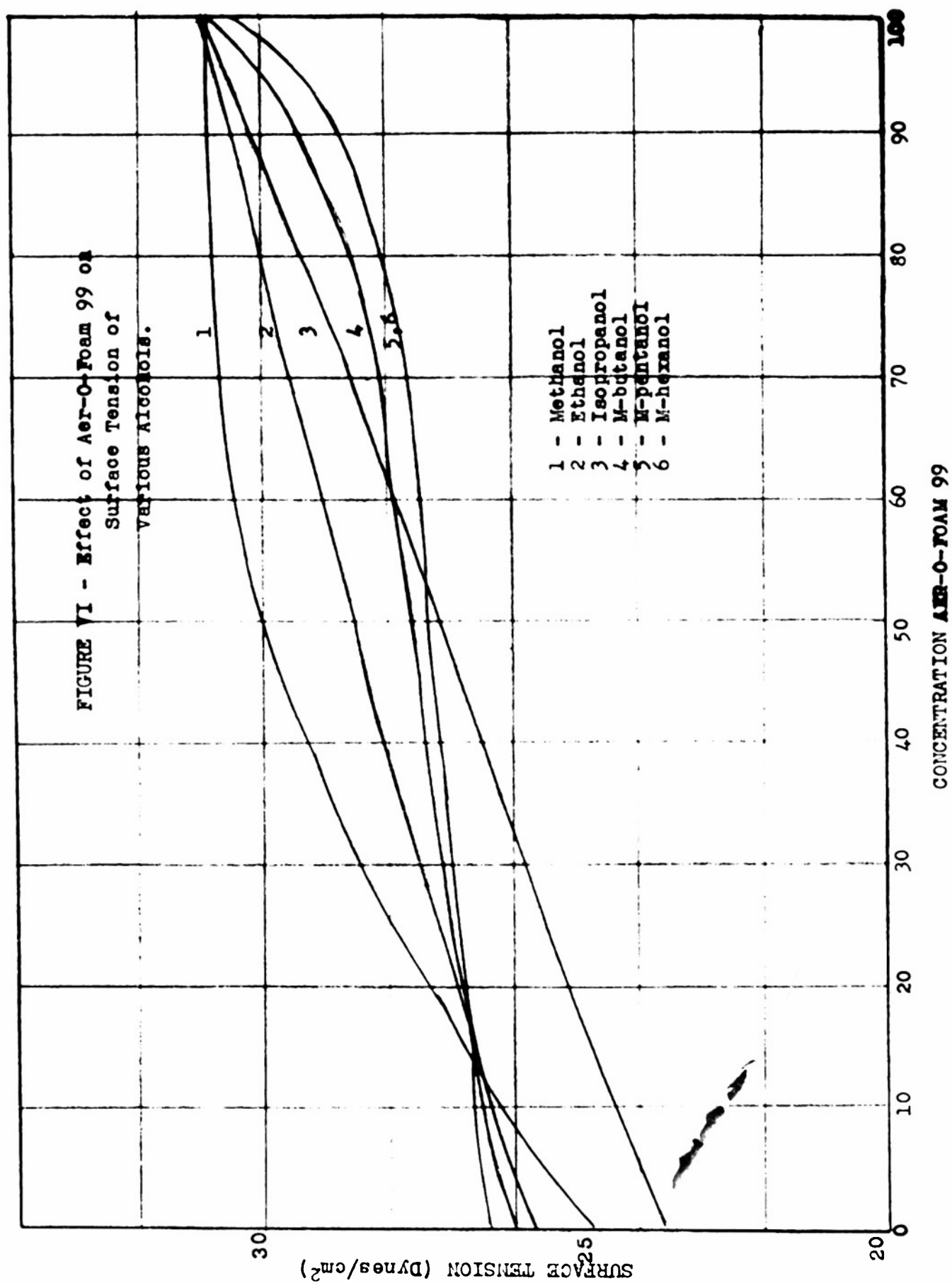
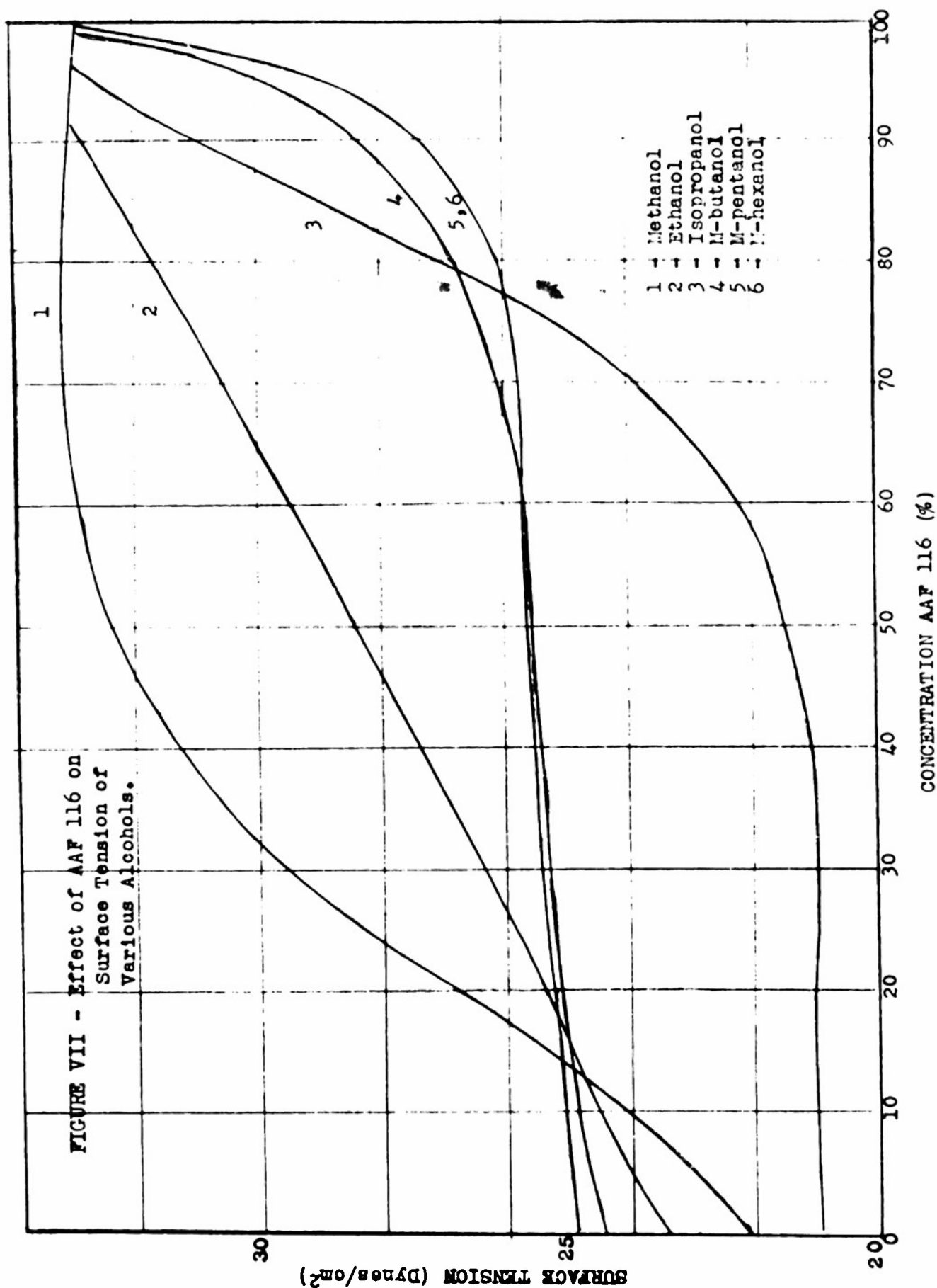
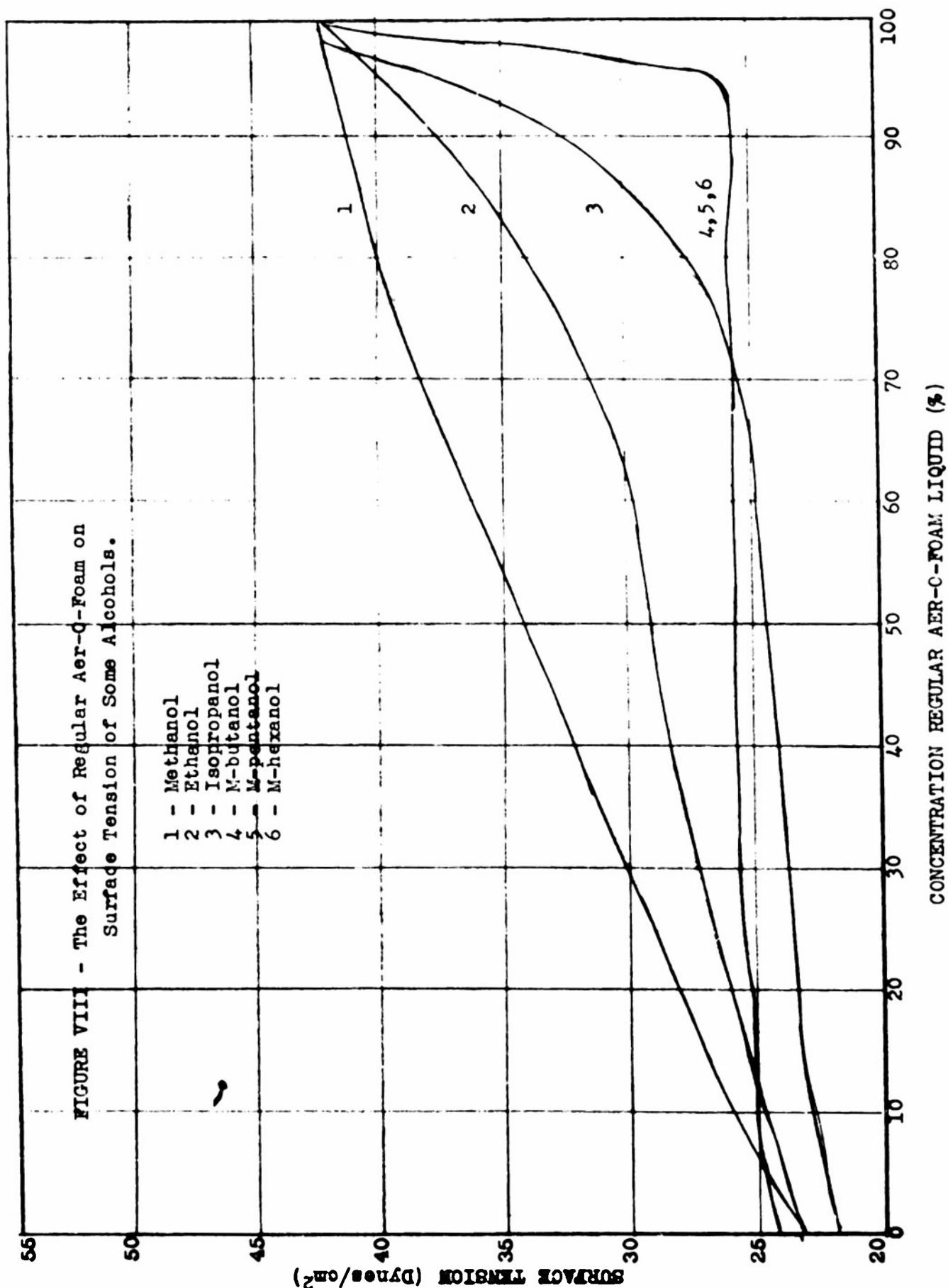
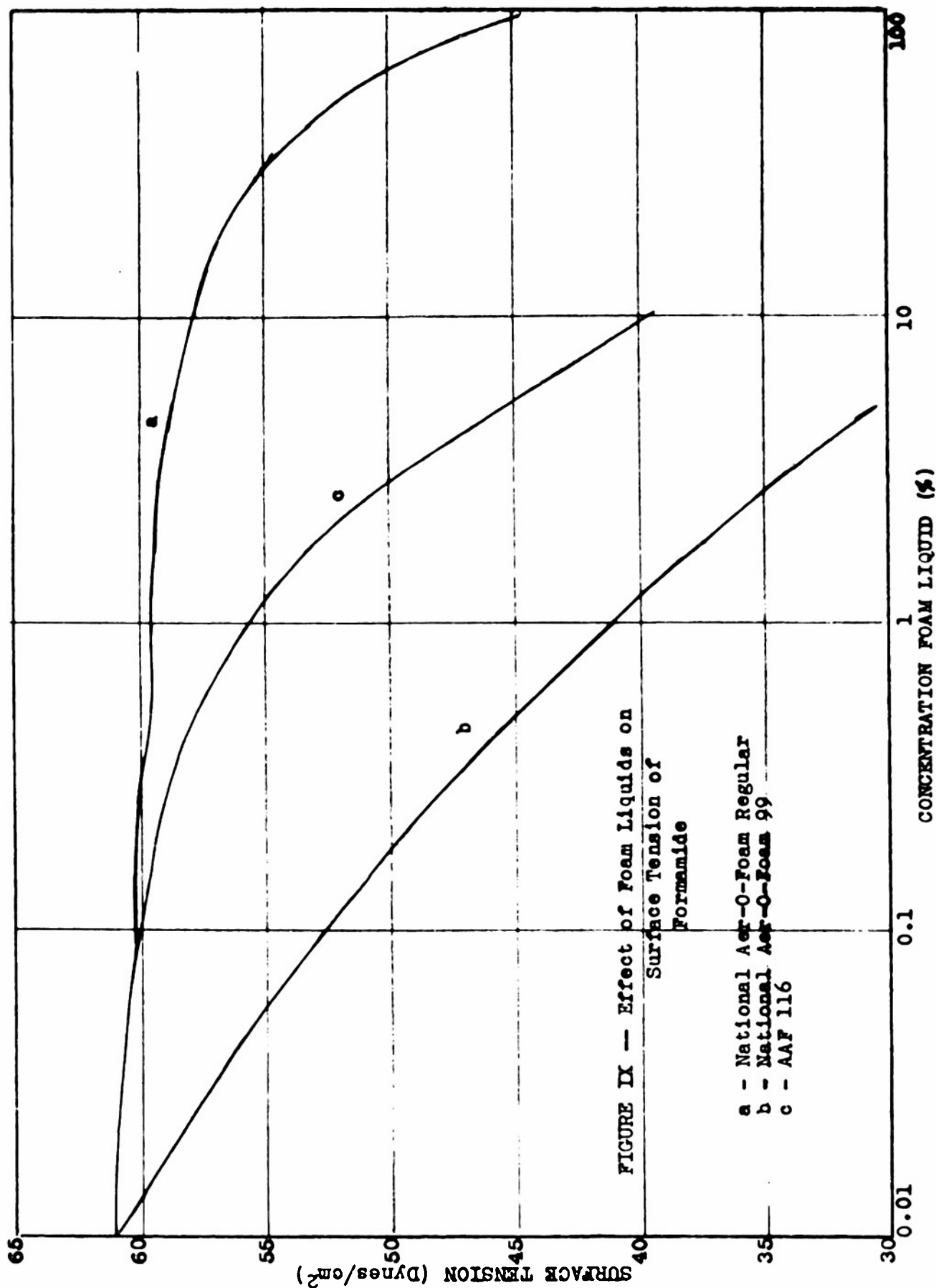


FIGURE VII - Effect of AAF 116 on Surface Tension of Various Alcohols.







SURFACE FILM STUDIES

Premix use of Aer-O-Foam 99 indicates a decrease in alcohol stability as the solution ages. A study was made of surface films. A difference was noted in gross appearance, i.e. formation of curds and in surface film measurements. In general it was found that film formed from aged solutions are more readily compressed. This might indicate decreased resistance to thermal or mechanical shock.